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Altitudinal distribution and anthropogenic influence on small mammal assemblages on Mount Kupe, SW Cameroon

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Abstract. We conducted a taxonomical inventory of small mammal biodiversity on Mount Kupe, SW Cameroon, the second inventory on that mountain after M. Eisentraut's more than 50 years ago. Our survey yielded a total catch of 19 species of mammals: 16 rodents, two bats, and one shrew. For each species we summarize data on natural history and discuss taxonomical and distributional aspects. We observed a difference between the rodent assemblages of the lowland (below 1000 m) (including *Praomys misonnei*) and the upper sub-montane and montane forest (1500–2000 m) (including *Hylomyscus* cf. *walterverheyeni*, identified for the first time from the Cameroon Mountains). This seems to correspond to previously described vegetation changes between 1000 and 1500 m. The inhabited and cultivated zones at the base of Mt. Kupe yielded eight widely-distributed rodent species. A number of taxonomical problems concerning montane forest species remain to be solved.

Keywords. Africa, Cameroon, Chiroptera, Rodentia, Soricomorpha, taxonomy, diversity.

1. INTRODUCTION

Tropical regions are well known to have a higher biodiversity than temperate regions. The forests of west-central Africa have been described as one of the tropical "hot spots" (MYERS et al. 2000; KUPER et al. 2005). African mountains seem to harbour a very important endemic diversity and are of exceptional conservation importance (HEIM DE BALSAC 1968; EISENTRAUT 1973; GENTRY 1992; STANLEY et al. 1998, 2005; KASANGAKI et al. 2003; HERRMANN et al. 2005; BURGESS et al. 2007). Both lowland and mountain forests are presently subject to intense deforestation. Several authors have emphasized the role of African forest refugia in promoting speciation during Quaternary climatic changes (MALEY 1987, 1996; QUEROUIL et al. 2003, PLANA et al. 2004; BEHNIN 2006, HUHNDORF et al. 2007). However, the knowledge of the mechanisms by which so many species arise and differentiate in such regions depends directly on a precise characterization of their biodiversity in relation to altitudinal and vegetation shifts along elevational gradients. The altitudinal effect on small mammal diversity is not well known and available studies differ in their results. According to some authors species-richness is not uniformly distributed on mountains, but the base and the top hold a higher diversity than the intermediate zones (BROWN 2001; LOMOLINO 2001). Other authors found a continuous decrease of diversity with elevation (DIAZ et al. 2002; KASANGAKI et al. 2003) or contrasting patterns in different taxonomic groups (HOFER et al. 2000). However, a positive correlation between species turnover and elevation was recently evidenced for rodents of different tropical mountains (MENA & VASQUEZ-DOMINGUEZ 2005). The authors considered climate, productivity and landscape heterogeneity as well as historical factors as possible explanations for elevational gradients.

There are many other vertebrate groups for which zonation has been described as a function of altitude in African mountains (e.g. EISENTRAUT 1968; AMIET 1987; STUART et al. 1987; KITYO & CLAUSNITZER 2001; KASANGAKI et al. 2003) but the observed changes seem to vary locally and their causes are not well understood. It is well known that the composition of plant communities changes along altitudinal gradients but the respective roles of vegetation or available streams versus altitudinal change remain un-

clear (Hofer et al. 2000). Because most terrestrial small mammal species are primary consumers or have limited dispersal capacities (restricted ranges and/or habitats) they are good models for studying altitude-diversity gradients.

Situated in the Central African forests blocks of the Guineo-Congolese hot spot of biodiversity and extending for about 1600 km, the Cameroon Volcanic Line (CVL) is a succession of high volcanoes and plateaus ranging in age between 30 and one Myr (Ubangoh et al. 1998). At a distance of about 3000 km from the Western Rift Valley of East Africa, it represents the second highest range of mountains in Africa, with Mount Cameroon at 4100 m and Mount Oku at 3011 m. Because of difficult access the Cameroon Highlands ecoregion has been poorly sampled for its small mammal fauna. Small mammal expeditions were launched by Eisentraut (1957, 1961, 1963, 1968), Lamotte (1950–1970, unpublished), and Schlitter et al. (1999), among others. These studies showed a high endemism of the region, particularly in Afro-alpine grasslands (above 2000–2500 m) and in mountain forests (Eisentraut 1963; Heim de Balsac 1968; Lamotte & Petter 1981; Petter 1986; Dieterlen & Van der Straeten 1992; Hutterer et al. 1992; Verheyen et al. 1997). Studies on other vertebrates and plants have also described many endemics, emphasizing the importance of this region (Stuart 1986; Amiet 1987; Sosef 1994; Larison et al. 2000; Cheek et al. 2004; Herrmann et al. 2005). Most previous biodiversity inventories focused on the two highest mountains (i.e. Mount Cameroon and Mount Oku). The biodiversity of the other mountains in the region is poorly known (summarized by Hutterer et al. 1992). Among the CVL highlands, Kupe Mountain (2064 m) harbours a well preserved mountain forest in the Bakossi Highlands. This forest is conserved on the western side of the mountain, thanks to the Bakossi people and a nature reserve project monitored by the World Wildlife Fund (WWF). While its vegetation has been extensively studied (Cheek et al. 2004; Tchiengue 2004), its small mammal diversity is less well known; Eisentraut (1958, 1963) published a faunal list for this mountain. Mt. Kupe is famous for the presence of ten primate species, among them drill (*Mandrillus leucophaeus*) and chimpanzee (*Pan troglodytes)* populations, which are threatened with extinction (Wild et al. 2004, 2005). The forest elephant (*Loxodonta africana cyclotis)* is also present on Mt. Kupe (Wild 2004). Numerous woody plant species of the lowland forest exhibit distinct sub–montane forest 'forms' (Letouzey 1985). Most of them still have no taxonomic status and were not included in assessments of diversity, endemism and the impacts of ecological change. Several studies (e.g. Breteler 1999; Mc Key 2000) have demonstrated the distinctness of sub-montane forest species, as well as their key role in understanding the history of the lineages concerned.

With this information as a background we concentrated our small mammal survey on the montane and sub-montane species. Our study should be of conservation value and provide further biogeographical hypotheses. In this paper we describe the composition of the small mammal community of Mt. Kupe along an altitudinal gradient. In order to better describe the Mt. Kupe small mammal community we made a morphological and molecular inventory of small mammal species to accurately describe the degree of endemism of the Kupe fauna, and eventually also look at a possible altitudinal difference between sub-montane and montane communities. This should further allow us to evaluate the importance of the CVL for small mammal biodiversity conservation and diversification.

1.1. Background

Previous information on the Mt. Kupe small mammal fauna: Small mammals from the Cameroon Volcanic Line (CVL) were described by Sanderson (1940) and Eisentraut (1957, 1961, 1963, 1968, 1969). They mainly studied the small mammals from Mt. Cameroon and Bioko Island, but also collected specimens from the massif of Mt. Kupe. M. Lamotte's surveys (1970–1975) followed and his collections allowed the description and rehabilitation of endemic species in the Bamenda Highlands (Lamotte & Petter 1981; Petter 1986; Musser & Carleton 2005), but not the Bakossi Highlands. In an unpublished report Dowsett-Lemaire & Dowsett (1998) provided a faunal list of the Bakossi Mountains. This list contained a great number of unidentified species.

The study area: Mt. Kupe is situated on the western slopes of the CVL. It is a steep-sided massive horst block formed during Cameroon's third eruptive phase in the Quaternary (Wild 2004). Mt. Kupe is the youngest mountain of the Bakossi Highlands. The mountains of this highland are among the wettest areas in Africa (around six to seven metres annual rainfall, Cheek et al. 2004). Approximately 80 % of it occurs in the April-October wet season but in general every month of the year experiences rainfall. Nevertheless, there is a dry season between November and March, and a single week or two of bright sunshine without rain usually occurs in July (the "short dry season"). Humidity is exceptionally high. The minimum relative humidity (81 %) is recorded during the dry season.

Descriptions of the Kupe forest vary from one author to another. All authors agree that the lowland evergreen forest occurs between 150 to 800 m and is restricted to the western and southern part of Mt. Kupe. The sub-montane forest is found from 800 m asl to the summit; Cheek et al. (2004) consider it to be constituted by mid-altitude forest and Afro-montane rain forest. Previously, Thomas

(1986) recognized only two forest types: the lowland forest below 1600 m and the sub-montane forest above. This classification is not followed by Lane (1994) or by Cheek et al. (2004). The sub-montane forest is characterized by the presence of *Podocarpus milanjianus* (Podocarpaceae) around 1600–2000 m, *Santiria trimera* (Burseraceae) and numerous large Guttiferae (Clusiaceae) of the genera *Allanblackia, Pentadesma*, and *Symphonia* between 1000 m and 2000 m, and *Cola* (Sterculiaceae) also between 1000 m and 2000 m (Letouzey 1968). Letouzey (1968) divides the sub-montane forest into three blocks. According to Cheek et al. (2004) this point of view was based mainly on aerial observation and it is possible that the band of vegetation influenced by human activity in this area was misinterpreted as sub-montane thicket. Cheek et al. (2004) divided the sub-montane forest into two altitudinal types: the lower sub-montane forest (800–1400 m), harbouring a high epiphyte and saprophyte diversity with some of the Bakossi Highlands endemics, and the upper sub-montane forest (1400–1900 m) which is less diverse. According to Cheek et al. (2004) there is also a montane forest (from 1900 m to the summit), characterized by the absence of *Clausena anisata*, *Laesa lanceolata*, and *Pavetta hookeriana*, all otherwise frequent in montane forests of the Cameroon Highlands. On the other hand, it contains many endemic species such as *Leptoderris fasciaculata*, *Batesanthus purpureus* (also sub-montane), *Ficus oreodryadum*, *Zanthoxylum leprieurii*, and *Aframomum zambeziacum*. A patch of mountain grassland is found on each of the three peaks of the summit which are up to 100 m wide only (Cheek et al. 2004). These mountain grasslands are constituted by two species only: *Panicum hochstetteri* and *Gladiolus aequinoctialis*.

2. MATERIALS AND METHODS

Small mammals were trapped during three periods of fieldwork. December 2005: around Nyasoso (N 04° 50' / E 09° 40') and on the mountain below at 950 m; February 2006: between 1500 m and 2000 m; August 2006: around 1000 m (Table 1). Lines of 250 Sherman traps baited with peanuts, flour, oil and dry fish were used each time and were set in six habitats: cultivated lowland and secondary forest (100–800 m), lower sub-montane forest (900–1000 m), upper sub-montane forest (1500 m), montane forest and montane grassland (2000 m). The traps were checked twice per day. Additionally, a number of traditional traps set by hunters were put randomly in the surroundings of Nyasoso village and at the summit. We also put two mist nets at the entrance of a cave (900 m asl) during two nights in December 2005 in order to catch Chiroptera. Due to logistic constraints the number of trap nights varied between habitats. Standard external measurements (weight [W], head and body length [HB], tail length [TL], ear [E] and hindfoot lengths [HF]) and the sex of each animal were taken. All animals were autopsied. The liver was kept in 70 % ethanol for molecular identifications and the carcasses preserved in 4 % formalin, and the skulls cleaned. All this material was included in the MNHN collections, Paris. Comparisons were performed with specimens previously collected from Cameroon (Nditam and Dja regions), Gabon (Makokou, Belinga) and Central African Republic (La Maboké). All species were identified based on information published in Rosevear (1969), Vivien (1991) and Wilson & Reeder (2005).

For species identification we performed classical morphometric analysis on both external and cranial distances, using a digital caliper (MITUYOTO, precision 0,01mm) and the protocol described by Denys & Tranier (1992). Due to the abundance of sibling species in tropical Africa, 81 specimens were sequenced by one of us (ADM) for confirmation of identification (Cytochrome b and/or 16S genes). These specimens were compared using the Neighbour Joining Tree Analysis and the sequences available in Genbank.

To study the small mammal communities, we used the Shannon-Wiener diversity index $H = -\sum_{i=1}^{S} p_i \ln p_i$ as a direct measure of species diversity in each habitat, as well as a correspondence analysis on presence-absence data. The correspondence analysis CFA (Benzecri & Benzecri 1984) was performed on the presence-absence of species in different habitats. By reducing the number of variables and using the chi-square distance, this method allows the representation of the relationship between variables (here habitats) and individuals (here species) on the same graph (scatter plot type) and gives an overview of the distribution of species diversity. All statistical analyses were performed by using XLSTAT 7.1 software (Addinsoft).

3. RESULTS

3.1. Trapping success, faunal lists

In total, 98 small mammals belonging to 19 species were captured on Mt. Kupe. Overall trap success with Sherman traps was 3,03 %. This varied among habitats: trap success was always low in the forest, varying from 1,86 % to 2,88 %, depending on the altitude; it was higher in habitats under anthropogenic influence (5,51 %; Table 2). The Shannon diversity index indicates quite an equal distribution of species abundances in the habitats under anthropogenic influence and the low diversity of the sub-montane and montane forests.

Table 1. Characteristics of the different habitats investigated and periods when they were sampled.

Sampling period	Elevation range (m)	Main vegetation investigated	Main habitats	GPS coordinates	Collecting method
Dec 2004 beginning of dry season	850	anthropogenic	farmland	–	Traditional traps
		lowland forest	closed canopy	–	Traditional traps
		anthropogenic lines A,B,C,F	fallow, farmland	N 04° 50' 10,1"/ E 09° 40' 48,5"	Sherman traps (60)
Dec 2005 beginning of dry season	850–950	anthropogenic	home garden	N 04° 50' 09,6"/ E 09° 40' 51,2"	Sherman traps (40)
		lowland forest lines D,E,T,U,V	closed canopy	N 04° 49' 26,0"/ E 09° 41' 11,9"	Sherman traps (160)
	850	anthropogenic line C	fallow, farmland, home garden	N 04° 50' / E 09° 40'	Sherman traps (100)
Febr 2006 end of dry season	1500–1600	sub-montane forest lines O,P,Q,R,S	closed canopy, dense under story	N 04° 49' 08,7"/ E 09° 42' 27,1"	Sherman traps (250)
	1900–2000	montane forest lines K,L,M	closed canopy	N 04° 47' 51,1"/ E 09° 42' 11,2"	Sherman (250) and traditional traps
		montane grassland lines I,J	woodland, savannah	N 04° 47' 52,7"/ E 09° 42' 23,9"	Sherman traps (250)
August 2006 little dry season	850	lowland forest	closed canopy	N 04° 49' 26,0"/ E 09° 41' 11,9"	Sherman traps (250)

Table 2. Details of trapping efforts and success in each habitat sampled. The trapping success corresponds only to animals captured in Sherman traps and the Shannon Index was calculated on pooled Sherman + Traditional trap captures in all habitats.

Species/Trap success/Diversity/H'	Anthropogenic		Lowland forest		Sub-montane forest		Montane forest 2000m	
	Sher	Trad	Sher	Trad	Sher	Trad	Sher	Trad
Crocidura poensis complex	4	0	1	0	0	0	0	0
Cricetomys cf. *emini*	0	1	0	0	0	0	0	3
Dendromus sp.	0	1	0	0	0	0	0	0
Deomys ferrugineus	0	0	0	0	2	0	0	0
Grammomys poensis	2	1	0	0	0	0	0	0
Hybomys cf. *univittatus*	0	0	1	0	0	0	0	0
Hylomyscus walterverheyeni	0	0	10	0	12	0	12	0
Hylomyscus sp.	0	0	1	0	0	0	0	0
Lemniscomys striatus	2	0	0	0	0	0	0	0
Lophuromys cf. *sikapusi*	0	3	0	0	0	0	0	0
Malacomys longipes	0	0	3	0	0	0	0	0
Mastomys natalensis	1	0	0	0	0	0	0	0
Mus musculus	0	2	0	0	0	0	0	0
Mus setulosus	4	1	1	0	0	0	0	0
Oenomys hypoxanthus	8	3	0	0	0	0	0	0
Praomys jacksoni	2	1	0	0	0	0	0	0
Praomys misonnei	0	0	13	0	0	0	0	0
Sherman trap nights	471	-	1041	–	751	–	637	–
Sherman captures	23	13	30	0	14	0	12	3
Trap success per night (%)	**5.51**	**–**	**2.88**	**–**	**1.86**	**–**	**1.88**	**–**
Diversity	**7**	**8**	**7**	**0**	**2**	**0**	**1**	**1**
H' (pooled Sher+Trad/habitat)	**0,921**		**0,456**		**0,178**		**0,217**	

Table 3. Means and ranges for the standard external measurements [mm] of the Mt. Kupe rodents.

Measurements	HB	TL	HF	E
Oenomys hypoxanthus (n=11)	149 (110–168,5)	177,3 (151–194)	31 (23–36)	18 (13–20)
Malacomys longipes (n=3)	137,7 (130–142)	161 (151–167)	35,3 (32–35)	20,3 (20–21)
Lemniscomys striatus (n=2)	109–122	111–115	25–26	15–16
Mus setulosus (n=5)	74,9 (63,5–84)	53,5 (50–57,5)	14,8 (14–16)	11,7 (10,5–14)
Hybomys cf. *univitatus* (n=1)	160	93	28	15
Grammomys poensis (n=3)	122 (116–133)	178,7 (171–189)	25 (21–28)	15,3 (15–16)
Hylomyscus walterverheyenei (n=28)	89,2 (74–103)	129,34 (112–150)	18,22 (12–21)	14,56 (13–16)
Hylomyscus sp. (n=1)	73	112	19	16
Praomys jacksoni (n=3)	120,3 (100–132)	125 (113–139)	24,3 (24–25)	18 (16–19)
Praomys misonnei (n=10)	117,9 (100–197)	133 (115–160)	23,65 (21,5–28)	17,25 (15,5–19)
Dendromus sp.(n=1)	55	84	19	10
Cricetomys emini (n=3)	347,7 (340–358)	371 (350–391)	66 (65–67)	39,7 (39–40)
Lophuromys cf. *sikapusi* (n=2)	130–142	59–70	20	17
Deomys ferrugineus (n=2)	119–137	172–191,5	33–36	25
Mastomys natalensis (n=1)	113,5	112	20	17

In total, 16 rodent species were captured. The most abundant species was *Hylomyscus walterverheyeni* (35, 80 % of captures), followed by *Praomys misonnei* (13,68 %) and *Oenomys hypoxanthus* (11,58 %). Only one shrew species (*Crocidura* cf. *poensis*) and two bat species (*Epomops franqueti* and *Myonycteris torquata*) were captured. The maximum diversity was found in the habitats under anthropogenic influence and in lowland forest. Eight species were trapped in the former habitat type, with *Oenomys hypoxanthus* and *Mus setulosus* being the most abundant. The absence of *Hylomyscus* cf. *walterverheyeni* from this habitat type is noteworthy, compared to its general abundance in the natural types. In the lowland forest *Hylomyscus walterverheyeni* and *Praomys misonnei* dominate the assemblages. The montane grassland yielded no captures. The sub-montane and the montane forest habitats' diversity are low with two species each and are characterized both by the presence of *Hylomycus walterveheyeni*.

3.2. Species records, characteristics and systematic notes

In this species account we provide morphological and/or habitat characteristics for each species. Where confusion with another species is possible we also provide results from skull analysis and cyt b or 16S DNA sequences analysis.

Order Rodentia

Family Muridae Illiger, 1811

Oenomys hypoxanthus Pucheran, 1855

Six males and five females (one juvenile) of this species were recorded. Standard measurements are provided in Table 3. Our specimens displayed the characteristic red nose of the genus and an underside of white-orange colors ventrally, with a more intense orange-red part in the genital region. The back fur displays a mixture of long black guard and short red-yellow hairs. The tail is covered with small black scales and is naked except for a few scattered, very short hairs. The Kupe specimens fall within the size range of specimens from Mount Cameroon (Eisentraut 1963) and S Nigeria (Happold 1987). *Oenomys hypoxanthus* shows appreciable geographic variation in fur color and body size; in Cameroon it was also captured in Nyasoso, Buea, Musake, Malende and Mueli (11 specimens) (Eisentraut 1963). During this inventory of the Mt. Kupe small mammal fauna, this species was only trapped at low altitude in Nyasoso village and in a fallow area with *Ageratum* spp. These results are congruent with the observations of Kingdon (1997) and Happold (1987), according to which *O. hypoxanthus* commonly nests in fallow ground and village gardens. It is generally restricted to forest below 2000 m.

Malacomys longipes Milne-Edwards, 1877

Three specimens (two males and one sub-adult female) were trapped in the forest along a river at an altitude of 850 m. They have a hindfoot longer than 34 mm (Table 3). The specimens from Nyasoso have a shorter ear (20–21mm) than those from Efulan (Cameroon) or Makokou/Belinga (Gabon) (25 mm), and their skull and body sizes are also smaller. These observed differences may have been a result of the low sample size of specimens captured from Nyasoso. MUSSER & CARLETON (2005) recognized the existence of three species within the genus *Malacomys*, among which only *M. longipes* is mentioned in Central and South Cameroon. However, *M. longipes* and *M. edwardsi* occur both in South Nigeria (HAPPOLD 1987). EISENTRAUT (1963) found only seven specimens of *M. longipes* in Batoki, Malende and Isobi (Cameroon) and only one on Mt. Kupe at 900 m, but mentioned a great variety of pelage colours in his sample. Similarly HAPPOLD (1987) also mentioned that Cameroon specimens of *longipes* show considerable variation, and some individuals are almost the size of the smaller *edwardsi*. However, the comparison of our cyt b sequences to those available in Genbank allows the definite identification of the three specimens as *M. longipes*.

Lemniscomys striatus Linnaeus, 1758

Two male striped rats were trapped in a maize field at Nyasoso village, 800 m asl. They fall within the size variability and color of *L. striatus* from Central African Republic (CAR), Congo and Cameroon and have molecular affinities with representatives from the region (NICOLAS et al. 2008a). A few earlier specimens had been collected in Nyasoso, Mt. Manengouba (EISENTRAUT 1973) and the Mamfe region (SANDERSON 1940).

Mus (Nannomys) setulosus Peters, 1876

EISENTRAUT (1957) attributed the Nyasoso *Mus* specimens to *M. musculoides*, but mentioned that they have a browner pelage than specimens from Buea and Mt. Cameroon. Later, EISENTRAUT (1968) corrected the identification and attributed the *M. musculoides* specimens to *M. setulosus*, which we confirm here on morphological and molecular grounds. The type specimen of *M. setulosus* comes from Limbe (formerly Victoria), less than 100 km S of Mt. Kupe. We obtained six pygmy mice (two males and four females) attributed to *Mus* (*Nannomys) setulosus*, based on their dark pelage, rather large size (Table 3), and the presence of a second lobe on the lower M3 (KOUASSI et al. 2008). They have been molecularly typed to confirm the identification (KOUASSI et al. 2008); TL is somewhat shorter than HB. All six specimens were trapped in zones influenced by human activities and in lowland forest. One subadult female had 2+2 mammae, the other female was a juvenile.

Mus musculus Linnaeus, 1758

Two *M. musculus* males were trapped by inhabitants in Nyasoso village. Cyt b analysis confirmed their identification.

Hybomys cf. ***univittatus*** (Peters, 1876)

One sub-adult male was recorded in lowland forest. Both skull morphology and cyt b analyses identified it as *Hybomys* (Table 4). EISENTRAUT (1968, 1973) described only *H. univittatus badius* from Nyasoso and Mt. Cameroon. But according to the same author *Hybomys u. badius* and *H. u. univitattus* coexist in Mamfe region. MUSSER & CARLETON (2005) mentioned taxonomic problems concerning the Central African *Hybomys* species, but confirmed three other forms in the Cameroon Highlands: *H. badius* on the Bakossi Highlands (Mt. Cameroon, Rumpi Hills), *H. eisentrauti* (described from Mt. Lefo, synonymized by MUSSER & CARLETON with *H. badius*) on the Bamenda Highlands, and *H. basilii* on the Island of Bioko. Further revision and discoveries of new specimens from both lowland and highland forests of the CVL pending, we attribute the Mt. Kupe specimen from lowland forest provisionally to the *univitattus* complex.

Grammomys poensis (Eisentraut, 1965)

Three specimens were caught in lowland forest and cultivated areas at Nyasoso village (Table 2). One of the two males was sexually active and the female was pregnant, carrying two embryos and displaying 0+2 mammae. Specimens were identified based on their very long tail (Table 3), ending with a small tuft, and by typical skull characteristics, notably the globular aspect of the braincase, microdonty, as well as the existence of a stephanodont crest on the molar cusps and presence of a t7 on the upper M12 (see review in PETTER & TRANIER 1975). Comparison with *G. gazellae* (put in synonymy with *G. macmillani* by MUSSER & CARLETON 2005) specimens from CAR and with *G. "rutilans"* (a synonym of *G. poensis*) from Gabon and with the holotype from Fernando Poo allows assignation of our new Kupe specimens to *G. poensis*. Yet, they are slightly smaller than the holotype which is a young adult. Two specimens were sequenced (cyt b) but a revision of the whole genus in West Africa is required before definite conclusions can be drawn. According to EISENTRAUT (1968) this species is absent from Mount Cameroon, but present in Mamfe (SANDERSON 1940) and on Bioko Island (EISENTRAUT 1965).

Hylomyscus walterverheyeni Nicolas et al. 2008

Thirty-four specimens of this rodent were trapped on Mt. Kupe at different altitudes (Table 4). Among the 12 females we found two juveniles, the other being adult with

2+2 mammae. Three females were each carrying four to five embryos. Ten of the 20 males were sexually active. Our identifications were confirmed through molecular analyses (cyt b and 16S gene sequencing). According to our preliminary molecular analyses, specimens from Mt. Kupe are the sister clade of the newly described species *H. walterverheyeni* (NICOLAS et al. 2008a, MISSOUP 2009). This species was described from the region between the Sanaga River and the Oubangui and Congo rivers in Cameroon, Gabon, Central African Republic and Republic of Congo. However, the authors stressed the importance of conducting additional sampling in Western Cameroon, Nigeria and the Dahomey Gap region in order to precisely define the western limit of its distributional range. Refined molecular analyses and multivariate morphometrical analysis of cranio-dental measurements are necessary to confirm whether the Kupe individuals represent a distinct montane forest clade.

Hylomyscus sp.

One adult female of *Hylomyscus* was captured in the zone under anthropogenic influence and was molecularly similar to four specimens called "*Hylomyscus* taxon 2" by NICOLAS et al. (2006). These four specimens all came from the Korup National Park in western Cameroon. They undoubtedly belong to a new species. Waiting for a general revision of the genus and especially of the taxa found along the CVL, we provisionally call it "*Hylomyscus* sp." This female had a mammae formula of 2+2.

Mastomys natalensis (Smith, 1834)

One adult male specimen was trapped in Nyasoso village. An analysis of the cyt b gene confirmed its identification as *M. natalensis*. Because of the high morphological variability observed in this group and the low degree of specific distinctiveness (DENYS et al. 2007), we did not compare this specimen with other specimens morphometrically. Previously only one specimen of this species was trapped (EISENTRAUT 1968), and therefore it does not seem to be common in the CVL while it is abundant in West Africa (DENYS et al. 2005) and in Nigeria (HAPPOLD 1987).

Praomys Thomas, 1915

Based on molecular analyses and the identification key of LECOMPTE et al. (2001) the Mt. Kupe specimens belong to two different species. EISENTRAUT (1968) only recorded one *Praomys* species, *P. morio*, from Mt. Cameroon.

Praomys jacksoni (de Winton, 1897)

In our study this species is represented by one female, one male and one juvenile which were all trapped and brought to us by Nyasoso villagers (Table 4). The mammae formula was 1+2. This species is recognized by its well-developed supra-orbital crests and the presence of a clearly separated t3 on M1 (LECOMPTE et al. 2001). A comparison of our 16S and cyt b sequences with those published by NICOLAS et al. (2005) and by LECOMPTE et al. (2002) confirmed our identification.

Praomys misonnei Van der Straeten & Dieterlen, 1987

Five females and eight males were trapped in the lowland forest (Table 2). Based on the absence of supra-orbital crests and their molar morphology they clearly belong to the so-called *tullbergi* complex. The females have a mammae formula of 1+2. A comparison of our 16S and cyt b sequences with those published by NICOLAS et al. (2005) and LECOMPTE et al. (2002) confirmed our identification.

Subfamily Deomyinae Thomas, 1888

Deomys ferrugineus Thomas, 1888

Two specimens were captured at c. 1500 m asl on Mt. Kupe (Table 2). This is surprising since EISENTRAUT (1963) only obtained this species in the lowland forest, six specimens in Nyasoso and at "Lager V" (western part of Mt. Cameroon) at 600 m.

Lophuromys cf. ***sikapusi*** (Temminck, 1853)

We trapped only one male and one female; one badly damaged specimen (sex unknown) was brought to us by the villagers. All specimens were trapped in the village. They are characterized by a red belly and a short tail (Table 4). The female had 1+1 mammae. Recently, *Lophuromys* taxonomy and systematics in Central, West and East Africa has been under debate. According to MUSSER & CARLETON (2005), the *Lophuromys sikapusi* complex may be represented in S Cameroon by different species, following VERHEYEN et al. (1997, 2000). Numerous sibling species are found within this complex. A molecular revision is necessary in order to precisely identify the specimens from Mt. Kupe.

Family Nesomyidae Major, 1897

Subfamily Dendromurinae G. M. Allen, 1939

Dendromus sp.

Only one adult male was captured in a crop field. According to MUSSER & CARLETON (2005) and EISENTRAUT (1968, 1973), *D. messorius* in the Cameroon highlands is

known from Manengouba and Nyasoso, and from the holotype from Efulen. The species is a typical inhabitant of tropical lowlands and lower mountain slopes. In the same region, Eisentraut found *Dendromus oreas* at higher altitudes (1850 m and 3000 m on Mt. Cameroon). MUSSER & CARLETON (2005) mentioned the high variability in *D. oreas* from West Central Africa. Our "new" specimen is smaller than *D. messorius* and *D. oreas* of the CVL. In size and skull morphology it is close to specimens in the Paris Museum from Belinga, Gabon, identified as *D. mystacalis*. The specimen from Mt. Kupe is also smaller than *D. messorius* from CAR. Pending further comprehensive revision of the genus in West-central Africa, we leave this specimen as unidentified.

Subfamily Cricetomyinae Roberts, 1951

Cricetomys cf. ***emini*** Wroughton, 1910

Four *Cricetomys* individuals (three males and one undetermined) were brought to us by hunters. They were obtained by traditional traps placed in Nyasoso village and in the forest near the top of the mountain, at approximately 1950 m asl. EISENTRAUT (1968) described 11 specimens from Buea, Nyasoso, Kumba and Mt. Cameroon as *C. gambianus poensis*. MUSSER & CARLETON (2005) put *poensis* in synonymy with *emini* and recognize *C. gambianus* only in the sub-Saharan savannah belt. Our specimens fit within the external measurements range of variability provided by EISENTRAUT (1968), except for the shorter tail length. According to OLAYEMI (2008) both *C. gambianus* and *C. emini* are present in South Nigeria. Further molecular work will help to refine the taxonomy within this genus.

Table 4. External measurements [mm] of Mt. Kupe *Crocidura*.

	HB	TL	HF	E	W
mean	94,2	53,4	14,6	8,6	16,7
range	82–105	48–62	10–17	7–11	13–19

Table 5. External measurements [mm] of Mt. Kupe Chiroptera.

Species	W	HB	TL	HF + claw	FA
Epomops 1	66	122	10	20 + 2	80
Epomops 2	50,5	113	16	20 + 2	77
Myonycteris	14	65		10 + 0,5	44

Order Soricomorpha Gregory, 1910

Family Soricidae G. Fischer, 1814

Crocidura cf. ***poensis*** (Fraser, 1862)

Five medium-sized shrews were captured in Sherman traps (Table 2). We recovered four males and one female with 0+2 mammae. At least eleven species of *Crocidura* are known from SW Cameroon (HUTTERER 2005). According to size and morphology our new specimens fit within the *C. poensis* complex (P. Barriere, pers. comm.).

It should be noted that EISENTRAUT (1973) recorded 5 species of shrews, *Sylvisorex megalura*, *Sylvisorex ollula*, *Crocidura nigeriae/poensis*, *C. attila*, and *C. hildegardeae* from Nyasoso at 850 m.

Order Chiroptera Blumenbach, 1779

We used mistnets to sample the bat population of a cave 950 m asl in the lowland forest of Mt. Kupe. Two fruit bat species were collected.

Family Pteropodidae Gray, 1821

Epomops franqueti (Tomes, 1860)

This species displays white basal ear tufts, and males also have white epaulets. We collected two adult females of this species (Table 5). This species was quite commonly trapped by EISENTRAUT (1968) on Mt. Cameroon and at Lake Barombi Mbo, and he attributed these specimens to the subspecies *franqueti*, mentioning the considerable variability of the species over all of West Africa. Our specimens from Nyasoso are much larger than the average for his specimens (FA=57,4, TL=12, HB=91, HF=15; EISENTRAUT 1968) but are smaller than Nigerian specimens (FA=82–91; HAPPOLD 1987).

Myonycteris torquata (Dobson, 1878)

One male of the little collared fruit bat was trapped. This species has also been sampled by EISENTRAUT (1968) at "Lager V" and "Lager VI" of Mt. Cameroon and was listed in an unpublished report by DOWSETT-LEMAIRE & DOWSETT (1998). Our specimen has a smaller forearm length (44 mm) than specimens from Mt. Cameroon (average 57,4 mm; EISENTRAUT 1968) and Nigeria (HAPPOLD 1987) (Table 5).

4. DISCUSSION

4.1. Rodent species diversity on Mt. Kupe compared to results of previous studies

Our study confirms the presence of *L.* cf. *sikapusi*, *L. striatus*, *M. setulosus*, *O. hypoxanthus*, *H.* cf. *univittatus* and *D. ferrugineus* on Mt. Kupe (Table 6). The differences between our species list and those of previous studies mainly concern genera for which the taxonomy is under revision: *Praomys*, *Hylomyscus*, *Mus*, *Nannomys* and *Cricetomys*. Concerning the genus *Praomys*, we could not confirm the presence of *P. morio* on Mt. Kupe, as suggested by EISENTRAUT (1968). This species was described from Mt. Cameroon where it ranges at altitudes up to 3000 m. The validity of *P. morio* was never assessed by molecular data. Our results show that the specimens from Mt. Kupe correspond to *P. misonnei*, not to *P. morio*. If future molecular studies confirm the validity of *P. morio* it should be restricted to the high altitudes of Mt. Cameroon. We also confirmed the presence of *P. jacksoni*, as mentioned by EISENTRAUT (1973) and DOWSETT-LEMAIRE & DOWSETT (1998). These authors also cited *Hylomyscus stella* from Mt. Kupe. However, NICOLAS et al. (2008b) showed that *H. stella* is restricted to East Africa, and that the specimens from West Central Africa (from the Sanaga River to the Oubangui-Congo River) represent a new species, *H. walterverheyeni*. Our results suggest that this species could also be present on Mt. Kupe. More detailed molecular and morphometrical analyses, though, are necessary to confirm this conclusion. EISENTRAUT (1968) attributed *Mus* specimens from Nyasoso to *M. setulosus*, which we confirm here on morphological and molecular grounds. Concerning *Cricetomys*, DOWSETT-LEMAIRE & DOWSETT (1978) mentioned the presence of *C. emini* at 1500 m. However, molecular analyses in progress seem to indicate quite a large genetic variability.

Our inventory adds three species to the fauna of the Mt. Kupe: *Grammomys poensis*, *Mastomys natalensis*, and *Hylomyscus walterverheyeni* (previously recorded under the name *H. stella*) (Table 6). Despite its presence on Mt. Cameroon, the genus *Mastomys* was not previously recorded on Mt. Kupe. Similarly, EISENTRAUT (1957, 1968) did not list *Grammomys poensis* but indicated that it was trapped by SANDERSON (1940) in the Mamfe region. We also confirm the presence of *Malacomys longipes*, *Oenomys hypoxanthus*, *Deomys ferrugineus,* and *Mus setulosus* in Nyasoso. We failed to collect *Stochomys longicaudatus* (4 specimens collected in Nyasoso by Eisentraut) and *Hylomyscus aeta,* both easily identifiable based on morphological characters. *Stochomys longicaudatus* is known to be present in fragmented populations throughout its distributional range, and may be locally abundant (KINGDON 1997). In the Kupe area this species may be rare or may even have disappeared since 1963.

Like DOWSETT-LEMAIRE & DOWSETT (1998), we found the bat species *Epomops franqueti* and *Myonycteris torquata* in a cave in the lowland forest of Mt. Kupe. EISENTRAUT (1973) and FEDDEN & MCLEOD (1986) collected both species at the same altitude. They seem to be quite common on Mt. Bakossi and Mt. Cameroon.

The yield of shrews was poor as compared to previous studies (EISENTRAUT 1973) and does not allow any conclusion.

Our study indicates that the rodent fauna on Mt. Kupe has not changed much since the pioneer study of EISENTRAUT (1957). This may be a sign of the quality of conservation of this forest. It has also shown that the rodent diversity is quite high in comparison with other mountains of the CVL (Mt. Bakossi, Mt. Manengouba, Mt. Lefo, Mt. Gotel, Mt. Cameroon – see MISSOUP et al. 2006). With 16 species, however, it is lower than on Mt. Oku (MISSOUP et al. 2006). This may be due to the fact that few inventories have been performed on these mountains. All mountains may harbour more species than are currently known. However, our results may also be biased by the common species because of the low number of individuals captured despite our trapping efforts. All the possible habitats of the lowland and montane forest were investigated but our trapping success remained very low in all lines and in all seasons (Table 2). Trapping success was lower than that obtained for Mount Elgon montane forest (7,7–10%) (KITYO & CLAUSNITZER 2001), Kilimandjaro (4,5–36 %) (MULUNGU et al. 2008) or montane forests of the Albertine Rift mountains, SW Uganda (3,41–11,4 %) (KASANGAKI et al. 2003). In all these studies, the highest trapping success was obtained in disturbed or degraded habitats.

4.2. Community analysis

It is generally assumed that the diversity of small mammals decreases with altitude, or at least changes with changes in vegetation type. Vegetation types may play a crucial role in structuring small mammal assemblages. In order to test if these hypotheses apply to Mt. Kupe we performed a correspondence analysis on presence-absence data for rodents and shrews as a function of altitudinal vegetation levels.

The graph of axis F1 x F2 of the correspondence analysis displays a quite good separation between all habitats (Fig. 1). It is clear that zones under direct human impact are well characterized by a cohort of commensals (like *Mastomys*, *Mus* and *Rattus*), but also species which are frequent in secondary forest and crops (e.g. *Lemniscomys*, *Lophuromys*, *Dendromus*, *P. jacksoni*). The true forest habitats display a different diversity with marked differ-

Table 6. Comparisons of the faunal lists for Mt. Kupe based on different studies (x= presence).

Species	**This study**	**Dowsett-Lemaire & Dowsett 1998**	**Eisentraut 1957**	**Eisentraut 1968, 1973**
Crocidura poensis	x	x	x	x
Crocidura attila		x	x	x
Crocidura sp.			x	
Cricetomys gambianus			x	x
C. emini	x	x		
Dendromus sp.	x			x
Grammomys poensis	x			
Lophuromys sikapusi	x	x	x	x
Deomys ferruguineus	x	x	x	x
Lemniscomys striatus	x	x	x	x
Mastomys natalensis	x			
Mus musculus	x			x
Mus setulosus	x	x		x
Mus musculoides		x	x	
Oenomys hypoxanthus	x	x	x	x
Praomys jacksoni	x	x		
Praomys morio			x	x
Praomys misonnei	x			
Hybomys cf. *univitattus*	x	x	x	x
Hylomyscus walterverheyeni	x	?		
Hylomyscus sp.	x			
Hylomyscus aeta			x	x
Hylomyscus stella?		x		
Malacomys longipes	x			
Stochomys longicaudatus			x	x
Rattus rattus			x	x
Micropterus pusillus			x	x
Epomops franqueti	x	x		
Myonycteris torquata	x	x		
Nannonycteris veldkampi?		x		
Lissonycteris angolensis		x		
Roussettus aegyptiacus		x		
Megaloglossus woermanni		x	x	x
Kerivoula smithii			x	x
Hipposideros caffer				x
Hipposideros ruber		x		
Hipposideros cyclops		x		
Rhinolophys alcyone		x		
Pipistrellus eisentrauti?		x		
Tadarida thersites?		x		

ences between the lowland forests on the one hand, and the sub-montane and montane forests (1500–2000 m) on the other along the F2 axis. *Hybomys*, *Hylomyscus* sp., *Malacomys*, and *P. misonnei* are characteristic of the lowland forest and are true forest taxa also found in the lowland forests of Gabon (DUPLANTIER 1982; NICOLAS & COLYN 2003). *H. walterverheyeni* and *Deomys ferrugineus* are the only species found at 1500 and 2000 m (upper sub-montane and montane forests) on Mt. Kupe. EISENTRAUT (1957) showed for Mt. Cameroon that *Malacomys* and *Deomys* are lowland forest taxa (< 900 m) and that only *Praomys morio* and *Hylomyscus aeta* reach the higher levels (up to 3100 m and 2000 m, respectively). Other species of *Hylomyscus* are commonly trapped at high altitudes in East Africa: On Mt. Elgon *H. denniae* is found in the forest and bamboo zones up to 2875 m and 3100 m (KITYO

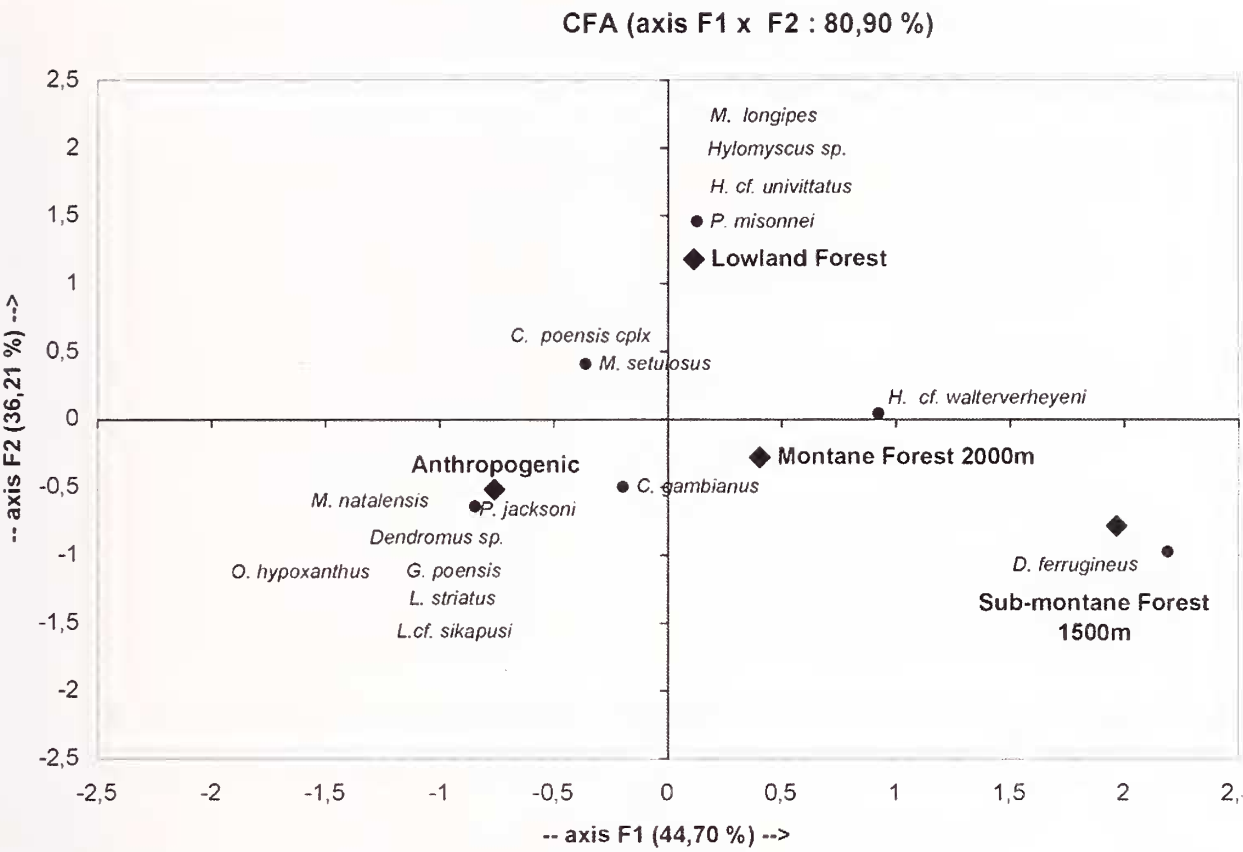

Fig. 1. Correspondence analysis scatter plot of axes 1 and 2 representing 80.9 % of the total variability based on presence-absence data for 16 species in the four general habitat types surveyed on Mt. Kupe.

& Clausnitzer 2001), while on Mount Rungwe *H. arcimontanus* is only found between 600 m and 2000 m (Carleton & Stanley 2005). In West and East Africa *Lophuromys roseveari, L. eisentrauti, L. flavopunctatus, Praomys jacksoni, P. morio, P. delectorum*, and *Colomys goslingi* are found above 2000 m (Dieterlen 1979; Verheyen et al. 1997; Kityo & Clausnitzer 2001; Mulungu et al. 2008).

In our study *Lophuromys* and *P. jacksoni* were only caught in zones under anthropogenic influence close to the village at around 800 m elevation. Eisentraut (1957) found *Stochomys, Cricetomys*, and *Dasymys* to be restricted to an altitude below 900 m, *Oenomys, Mus*, and *Lophuromys* reached 2100 m, and *Dendromus oreas* and *Otomys burtoni* were found above 2000 m. On Mt. Kupe we trapped *Deomys* at 1500 m, while *Cricetomys* is known from the summit (2000 m and above). On Mt. Elgon *Cricetomys* is also present at high altitude (3500 m) (Kityo & Clausnitzer 2001). In Bwindi, SW Uganda, species such as *Grammomys dryas, Hybomys* sp., *L. medicaudatus, rahmi, woosnami, H. aeta, denniae, vulcanorum, Mus bufo*, and *T. venustus* live in forests above 1800 m (Kasangaki et al. 2003). In lower elevation forests *H. stella, Praomys jacksoni, Praomys* sp., *S. longicaudatus*, and *T. kempi* occur. Other taxa like *Deomys, H. univittatus, O. hypoxanthus* found on Mt. Kupe, live in a wide range of habitats and may be found on the edge of forests.

Rodent species diversity in the area studied decreases drastically from lowland to sub-montane forest (Figure 1, Table 2) between 900 and 1500 m. This may correspond to the differences observed in vegetation composition. Both Letouzey (1985) and Tchiengue (2004) found floristic differences between the lowland forest and the montane forest, with some endemics occurring only above 1000m. Cheek et al. (2004) noted a floristic change from lowland to sub-montane forest on Mt. Kupe at 800 m. The very low diversity observed at 1500 m and 2000 m corresponds with the difference observed between a lower sub-montane forest (= very rich and diversified) and an upper sub-montane forest (= relatively poor) between 1400 m and 2000 m (Cheek et al. 2004). In comparing species turnover and elevation in small mammals for different

tropical mountain regions MENA & VASQUEZ-DOMINGUEZ (2005) found the highest turnover at intermediate altitude between 1000 m and 2500 m, but they did not attempt to define causes of such changes in species diversity. EISENTRAUT (1957, 1968) also described a change in vertebrate community composition on Mt. Cameroon: for amphibians between 800 and 1000 m, for reptiles around 900 m, and for small mammals at 2100 m. Studies are on the way to verify the altitudinal effect hypothesis for the other mountains of the Bakossi and Bamenda Highlands of the CVL (MISSOUP et al., unpubl).

4.3. Conclusion

The results of our small mammal survey suggest an absence of rodent species endemic to the high altitude forest of Mt. Kupe. Because recent work has revealed an unsuspectedly high cryptic diversity, molecular analyses are now necessary to validate this hypothesis. Our study has updated the Mt. Kupe faunal list with the addition of four species not recorded in previous studies. The Mt. Kupe diversity is relatively high when compared to other Central African forest areas. We present first evidence that the recently described *H. walterverheyeni* occurs at 2000 m and is absent from habitats under impact by humans, and that *Deomys ferrugineus* can reach altitudes of 1500 m. On the other hand, *P. misonnei*, *Malacomys*, and *Hybomys* are restricted to lowland forest below 900 m. We recovered almost all the true forest species previously collected from Mt. Kupe, suggesting a good preservation of the lowland forest. This is of importance for drill conservation because these primates have been encountered on Mt. Kupe from 700 m up to 2000m and they use all types of habitats on Mt. Kupe. Of the species previously mentioned for this area by Eisentraut we could not collect *Stochomys longicaudatus* and *Hylomyscus aeta* during this study. These two genera are inhabitants of the lowland forests of Central Africa. Little is known about their habitats and demography; their conservation status is 'Lower Concern' (BOITANI 2007; SCHLITTER & VAN DER STRAETEN 2007). The absence of *S. longicaudatus* and *H. aeta* may suggest a low population size. Moreover, the low trapping success we obtained during various seasons may indicate a general decrease of rodent abundance. This ought to be checked in the future because it may indicate an over-exploitation of forest rodents for bushmeat.

We observed a change in the small mammal community composition between lowland and sub-montane forest, suggesting a turnover occurring between 1000 m and 1500 m. We also observed a change in the community structure between areas under human impact and lowland forests, with different genera or species present and a rather good diversity in the undisturbed lowland forest. This stresses the importance of regular small mammal biodiversity surveys in close relationship with local vegetation associations on Mt. Kupe and more generally in hotspot zones to follow the forest condition.

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Zusammenfassung. Mehr als 50 Jahre nach M. Eisentrauts erster Bestandsaufnahme der Kleinsäuger-Fauna des Mount Kupe, SW Kamerun, unternahmen wir die zweite. Dabei konnten wir 19 Arten nachweisen: 16 Nager, zwei Fledermäuse, eine Spitzmaus. Für jede Art werden Daten zur Biologie, Verbreitung und Taxonomie zusammengefasst. Zwischen der Nager-Artengemeinschaft des Tieflandes (< 1000 m) (inkl. *Praomys misonnei*) und der der höher gelegenen Wälder (1500–2000 m) (inkl. *Hylomyscus* cf. *walterverheyeni* als Erst-Nachweis für das Kameruner Bergland) bestehen Unterschiede, die wahrscheinlich mit den bekannten Veränderungen der Vegetation zwischen 1000 und 1500 m Meereshöhe zusammenhängen. In bewohnten und landwirtschaftlich genutzten Gebieten am Fuße des Mount Kupe konnten wir acht weitverbreitete Nager-Arten nachweisen. Bei einigen Arten der montanen Waldgebiete bestehen weiterhin taxonomische Probleme.

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